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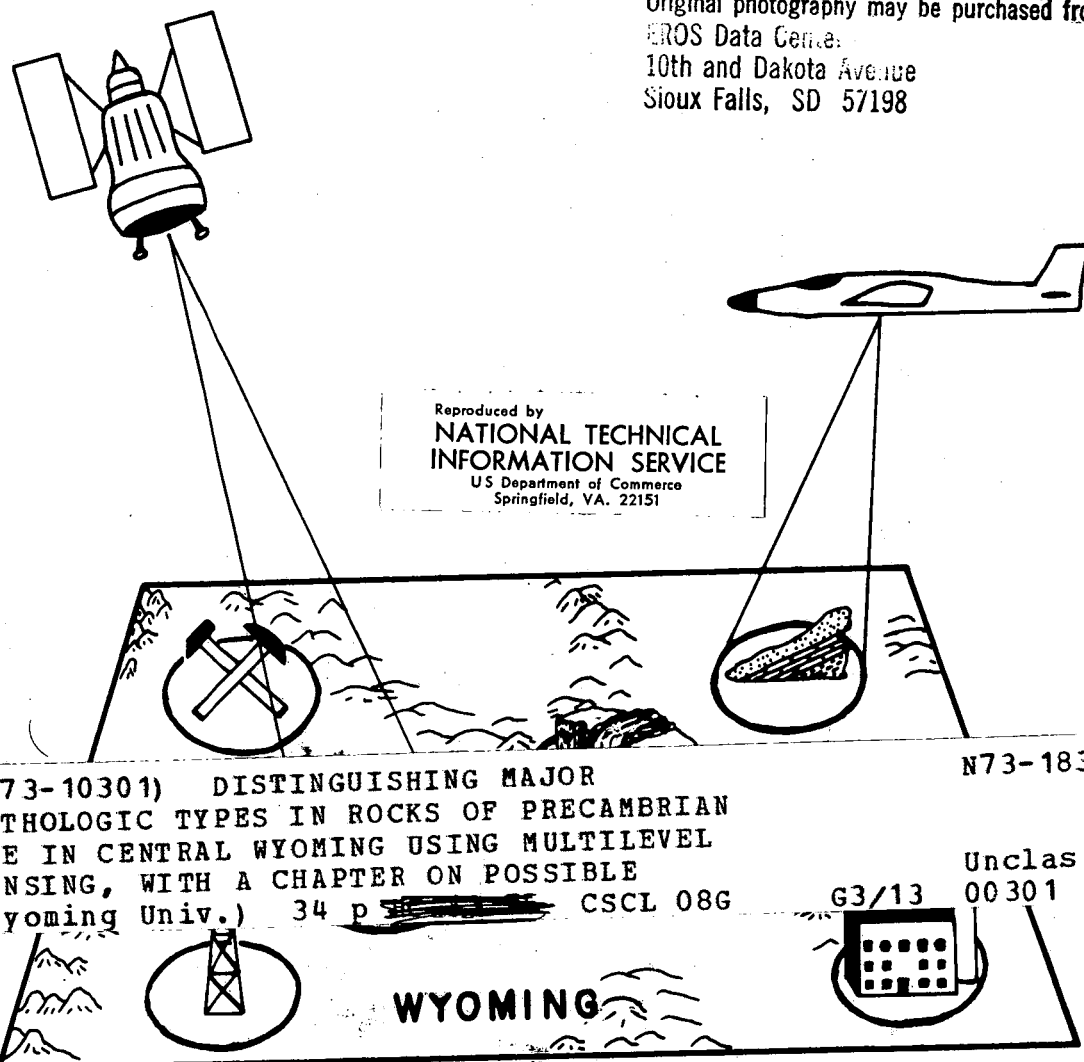
SPECIAL REPORT

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ROBERT S. HOUSTON

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DISTINGUISHING MAJOR LITHOLOGIC TYPES IN ROCKS OF PRECAMBRIAN AGE IN CENTRAL
WYOMING USING MULTILEVEL SENSING -- WITH A CHAPTER ON POSSIBLE ECONOMIC
SIGNIFICANCE OF IRON FORMATION DISCOVERED BY USE OF AIRCRAFT IMAGES IN THE
GRANITE MOUNTAINS OF WYOMING

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February 16, 1973
Special Report

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16. Abstract Information obtained by remote sensing from three altitude levels; ERTS (565 miles), U-2 (60,000 feet), and C-130 aircraft (15,000 feet) illustrates a possible application of multilevel sensing in mineral exploration. Distinction can be made between rocks of greenstone belts (mafic terrain of greater economic potential) and rocks of granite-granite gneiss areas (felsic terrain of less economic potential) by use of ERTS imagery in portions of the Precambrian of central Wyoming. Study of low altitude color and color infrared photographs of the mafic terrain revealed the presence of metasedimentary rocks with distinct layers that were interpreted as amphibolite by photogeologic techniques. Some of the "amphibolite" layers were found to be iron formation when examined in the field. To our knowledge this occurrence of iron formation has not been previously reported in the literature.			
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Figure 2. Technical Report Standard Title Page

DISTINGUISHING MAJOR LITHOLOGIC TYPES IN ROCKS OF PRECAMBRIAN AGE IN CENTRAL WYOMING USING MULTILEVEL SENSING -- WITH A CHAPTER ON POSSIBLE ECONOMIC SIGNIFICANCE OF IRON FORMATION DISCOVERED BY USE OF AIRCRAFT IMAGES IN THE GRANITE MOUNTAINS OF WYOMING.

By Robert S. Houston

INTRODUCTION

Parts of central Wyoming have been covered by remote sensing at three altitude levels within the period September 1971 - September 1972 by NASA aircraft and the Earth Resources Technology Satellite (Fig. 1). Aircraft flights at approximately 15,000 feet were made by NASA C-130 aircraft in September 1971 (Mission 184) and September 1972 (Mission 213). One aircraft flight at approximately 60,000 feet was made in October 1971 using NASA U-2 aircraft and coverage of the area is available from late August 1972 by the MSS sensor of the Earth Resources Technology Satellite.

These various images generated at different altitudes, have been used to distinguish major lithologies (i.e. granite-granite gneiss terrain vs. meta-sedimentary rock - metavolcanic rock terrain) in rocks of Precambrian age in portions of central Wyoming (Fig. 2).

Distinctions of this type are important in Wyoming because major mineral deposits in rocks of Precambrian age are usually confined to the metasedimentary rock - metavolcanic rock terrain, and a better outline of the extent of granite is useful in uranium prospecting because one concept (Masursky, 1962; Rosholt and others, 1971; Harshman, 1972) suggests that the major uranium deposits in Wyoming arkosic sandstone may contain uranium derived from adjacent granites of Precambrian age.

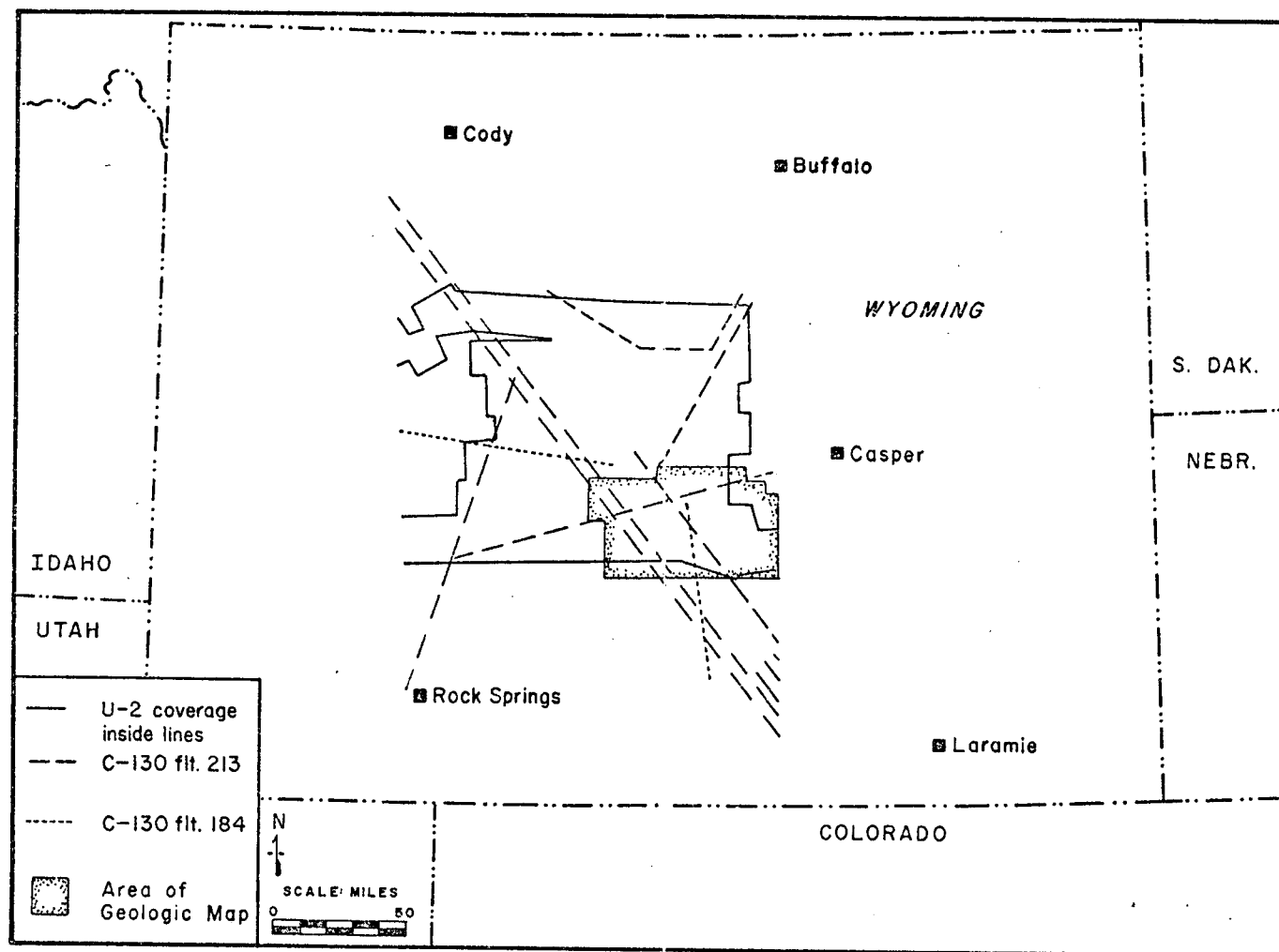


Figure 1 — Index map showing location of area in central Wyoming covered by flights of U-2 and C-130 aircraft, and area covered by geologic maps in figures 4, 5 and 6.

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Figure 2. Areal photograph of part of the eastern Granite Mountains of Wyoming, showing partially exhumed highlands of Precambrian age surrounded by a cover of Tertiary sedimentary rocks. Two highlands in the foreground and center of the photograph are granite and granite gneiss whereas the darker highland in the background is a mafic gneiss probably derived from metasedimentary or metavolcanic rocks. Note basalt dikes cutting granite body in the foreground.

Lithologic distinctions were made by photogeologic techniques using a Richards model MIM-3 viewer with a Bausch & Lomb Model 240 stereozoom microscope. Color and color infrared film positives were the most useful from the C-130 package and color infrared and red band film products were the most useful from the U-2 package. The MSS-5 band of the Earth Resources Technology Satellite was the band that gave the most satisfactory resolution of these geologic units.

Less bias in photogeologic interpretations results if images are studied in order of increasing resolution, that is, spacecraft to low-altitude aircraft. An attempt was made to do this whenever practical, but in this study some aircraft images were available and in use eight months prior to receipt of spacecraft imagery and results of study of Mission 184 aircraft imagery has in some degree biased the interpretation of U-2 and ERTS-MSS-5 imagery.

The major purpose of this study was to determine how useful the various bands of the MSS-ERTS sensor are for terrain distinctions of the type discussed above. If a satisfactory resolution can be made with ERTS bands, mapping can be done at substantial reduction in time and in expense of material.

The following discussion will treat each type or level of sensing separately starting with ERTS and ending with C-130 aircraft.

Precambrian Terrain Distinction Using ERTS-MSS Sensor

The results of a preliminary study using ERTS-MSS-5 band 9-inch positive transparencies for Precambrian terrain distinctions have been discussed by Houston and Short (1972, p. 11-13). At the time of this preliminary study (September, 1972) the only ERTS data available were the MSS-5 positive transparencies. Figure 3 shows the results of this preliminary study and as noted

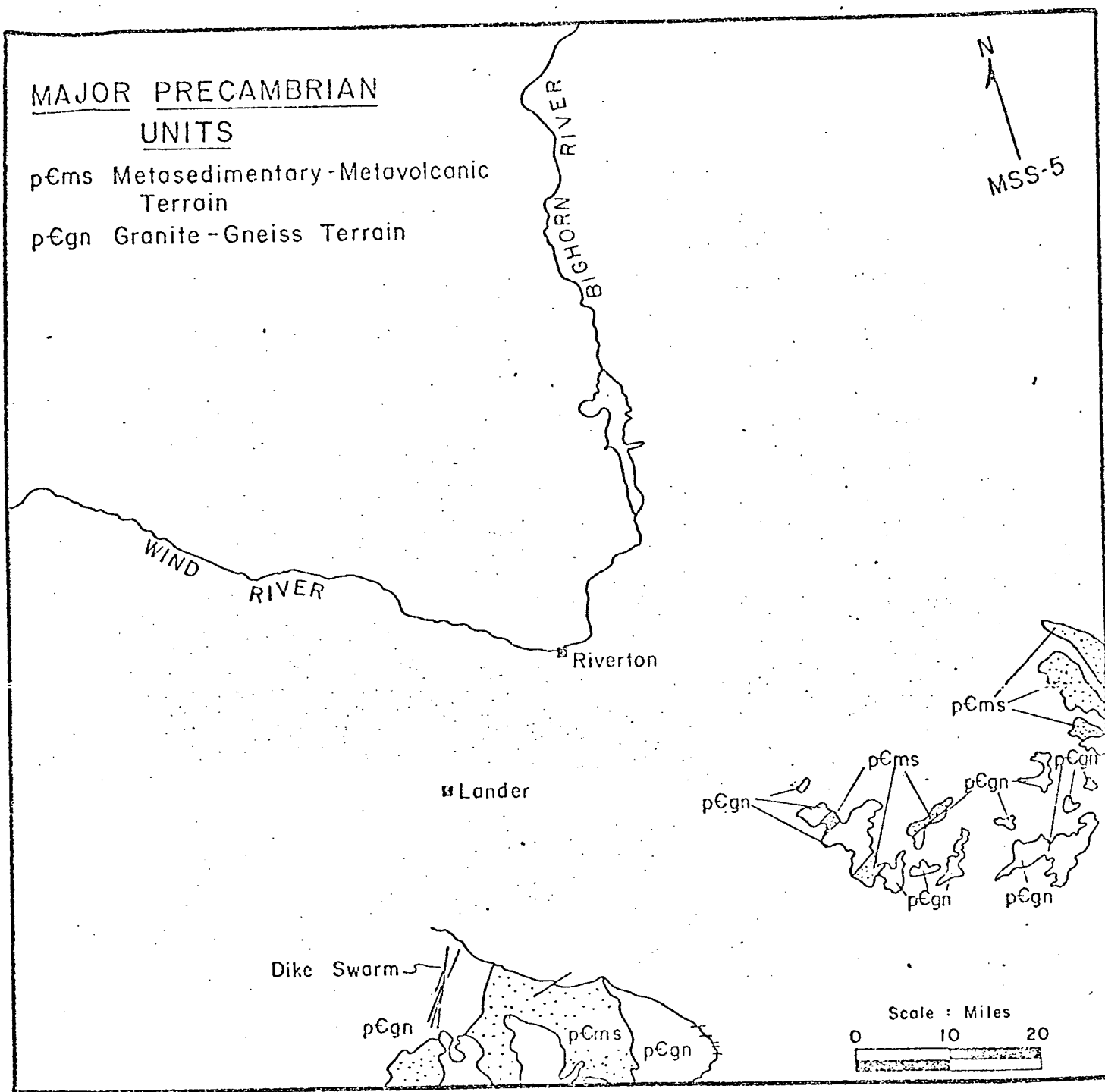


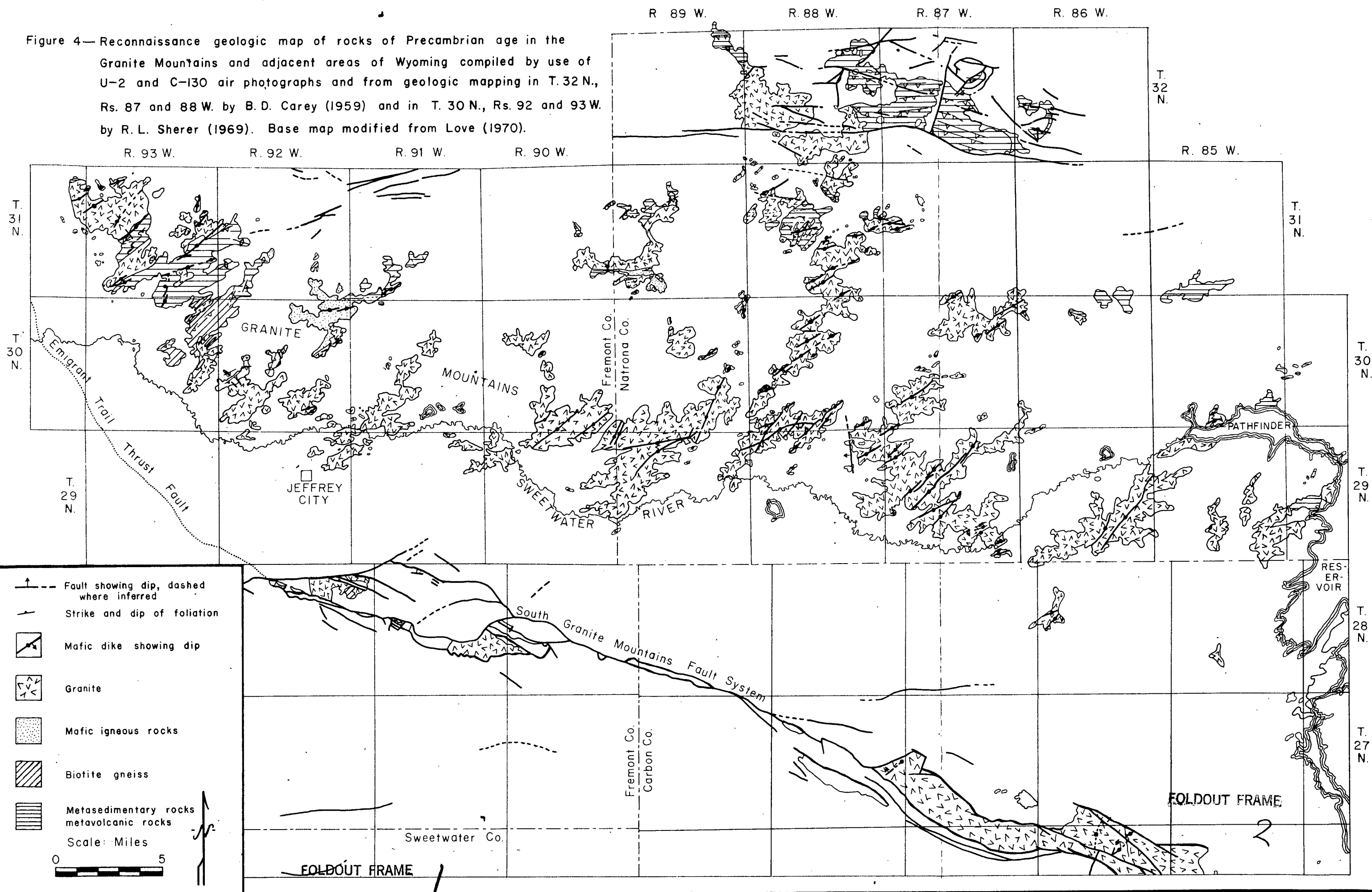
Figure 3. Map showing distribution of Precambrian metasedimentary rock - metavolcanic rock areas and granite-granite gneiss areas as determined by use of ERTS-MSS-5 film positives.

by Houston and Short (1972, p. 12) metasedimentary rock - metavolcanic rock terrain could be distinguished from granite-granite gneiss terrain quite well in the southeastern Wind River Mountains and to some degree in the Granite Mountains of Wyoming.

In the southeastern Wind River Mountains mapping by Bayley (1962a-d) and Bell (1955) gives adequate ground truth to enable us to evaluate the ERTS, MSS-5 interpretation. According to Bayley (1965a) the metasedimentary rock - metavolcanic rock terrain consists chiefly of light-brown to black feldspathic and micaceous graywacke, conglomerate and mica schist, and dark-colored mafic lava flows and bodies of gabbro, black graphitic schist, dark brown metaand-site flows, and lesser amounts of dark quartz-magnetite iron formation and white, gray, or pale green quartzite and pale green mica (fuchsite) schist. The terrain underlain by these rocks is dark colored and rather distinctly layered. The granitic terrain (Bayley, 1965c) may be gray quartz diorite and granodiorite or white to pink coarse-grained granite (Bell, 1955, p. 13). The granitic terrain, for the most part is light colored and texturally more massive than the metasedimentary - metavolcanic rock terrain. This tonal contrast shows quite well on MSS-5 with the metasedimentary - metavolcanic terrain indicated as areas of low reflectance and the granitic terrain as areas of higher reflectance.

Although similar distinctions can be made in the Granite Mountains the interpretation from the ERTS image is not as accurate as that of the southeastern Wind River Mountains. The accuracy of the interpretation may be judged by comparing Figure 3 (the ERTS interpretation) with Figure 4 which is a geologic compilation from the best available geologic and photogeologic mapping of this area. The major area of metasedimentary - metavolcanic rock in the northeast Granite Mountains can be distinguished but minor granite bodies within this area

Figure 4—Reconnaissance geologic map of rocks of Precambrian age in the Granite Mountains and adjacent areas of Wyoming compiled by use of U-2 and C-130 air photographs and from geologic mapping in T. 32 N., Rs. 87 and 88 W. by B. D. Carey (1959) and in T. 30 N., Rs. 92 and 93 W. by R. L. Sherer (1969). Base map modified from Love (1970).



cannot. In the southwest the general area where metasedimentary - metavolcanic rocks are present can be recognized from the ERTS-MSS-5 image but an area of metasedimentary rock approximately two miles wide and six miles long was misinterpreted as granite.

The difficulty in making distinctions between rock types in the Granite Mountains is probably the result of several factors. The Granite Mountains are interpreted (Love, 1970) as a once great mountain area like the Wind River Mountains that collapsed to form a graben. The mountains were buried by sedimentary rocks of late Tertiary age and, subsequently, these mountains were partially exhumed so that today we see isolated masses of rocks of Precambrian age surrounded by flat-lying sedimentary and volcanic sedimentary rocks of late Tertiary age (Fig. 2). Some masses stand well above the Tertiary floor and others are barely exhumed. In general, the granitic rock terrain has higher relief, less soil, and, as stated above, is light colored as compared to the metasedimentary - metavolcanic terrain. The higher reflectance in the red band of granitic terrain is probably a combination of all of these factors rather than a simple expression of rock color alone. In addition, some metasedimentary rock units in the Granite Mountains are more felsic in composition and lighter in color than those of the Wind River Mountains; and are difficult to distinguish from granite even with high-resolution color and color infrared photography. The various factors undoubtedly hinder lithologic distinctions in this area. This conclusion is supported by limited field checks and available ground truth.

Subsequent study of ERTS images (after the initial study reported by Houston and Short, 1972) using all bands and color-additive viewing technique failed to show significant improvement over the original study which employed only red band imagery. Atmospheric conditions for recording rock reflectance seem to

have been exceptionally good during the first ERTS pass (August 5, 1972) and subsequent passes through early November, 1972 have not produced images of this area of comparable quality.

Precambrian Terrain Distinctions Using U-2 Aircraft Film Positives

Figure 5 is a geologic map prepared from interpretation of U-2 red band and color infrared 70 mm negative transparencies. Resolution of the U-2 photographs was adequate to distinguish many of the large diabase dikes that cut the granitic rocks of this area so three Precambrian lithologies were mapped; granite-granite gneiss terrain, metasedimentary rock - metavolcanic rock terrain, and diabase dikes. The distinctions made using U-2 images are good as indicated by a comparison with Figure 4. In fact, in one area, T. 30 N., R. 92 W., the terrain contrast from the U-2 photography appears to be greater than that available from low-altitude aircraft (C-130) images of much higher resolution (Fig. 6).

Direct comparison of the U-2 photography with the Mission 184 (C-130) photography (Fig. 6) shows that only half as many dikes can be resolved on the U-2 photography as on the higher resolution C-130 photography. This is apparently a line resolution limitation rather than a reflectance difference because the wider dikes are clearly distinguished on the U-2 images.

Figure 7A and 7B compare U-2 and ERTS images of a granite-metasedimentary rock contact in the southeastern Wind River Mountains. In this area the U-2 has no advantage over the ERTS images inasmuch as the contact can be readily mapped with either image.

Figure 5—Reconnaissance geologic map of rocks of Precambrian age in the Granite Mountains of Wyoming compiled by use of U-2 air photographs. Base map from Love (1970).

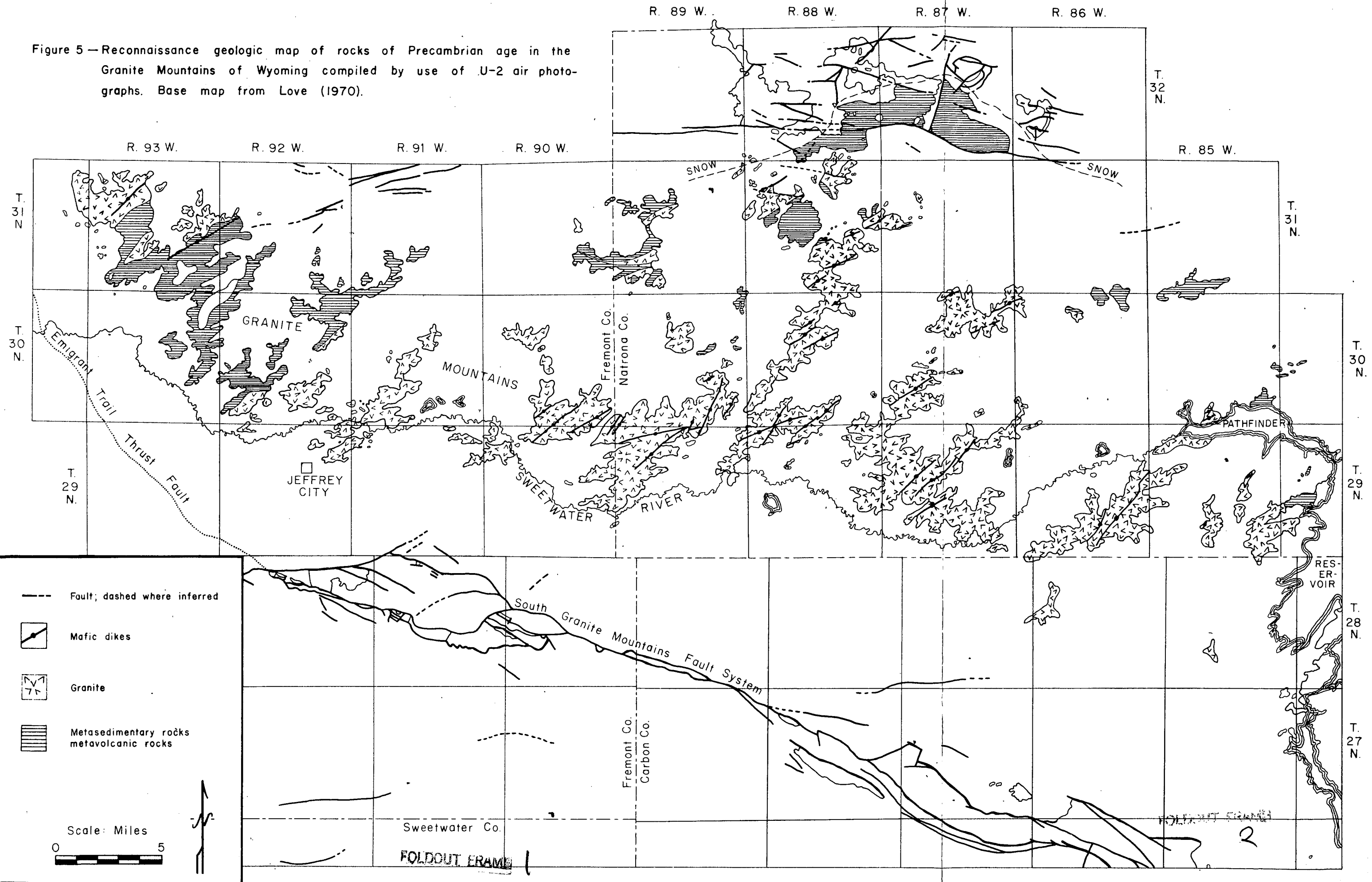
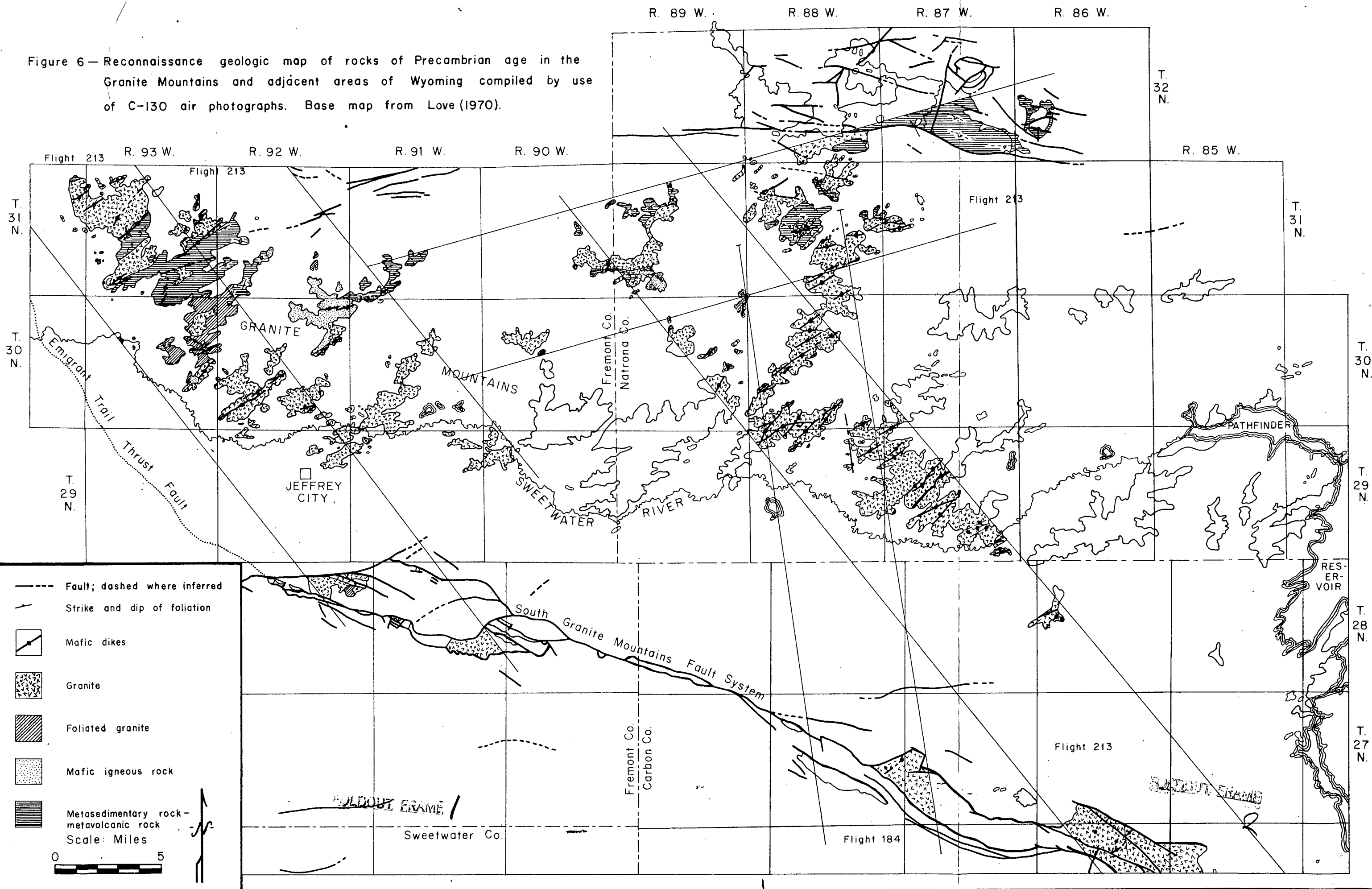
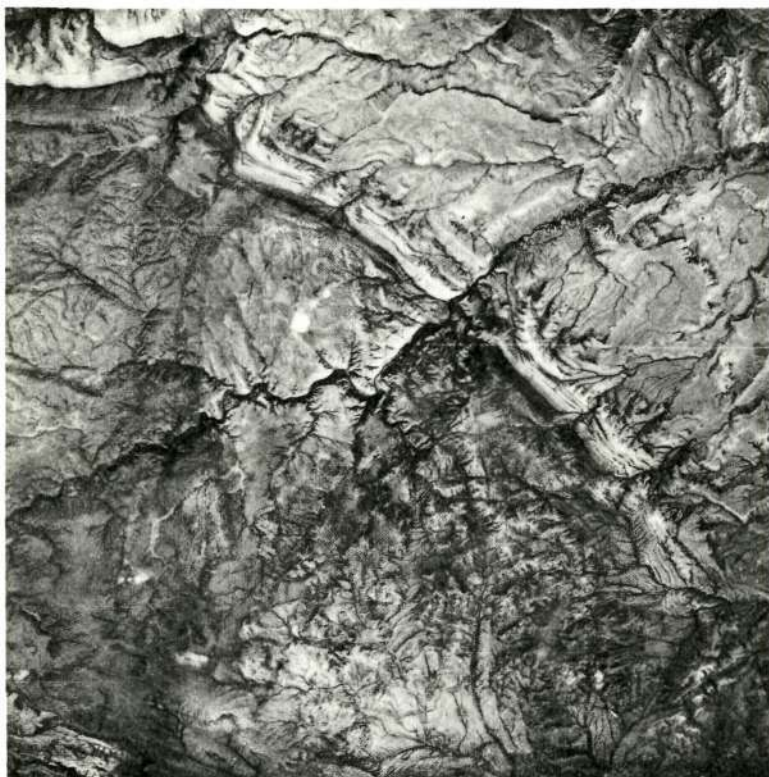


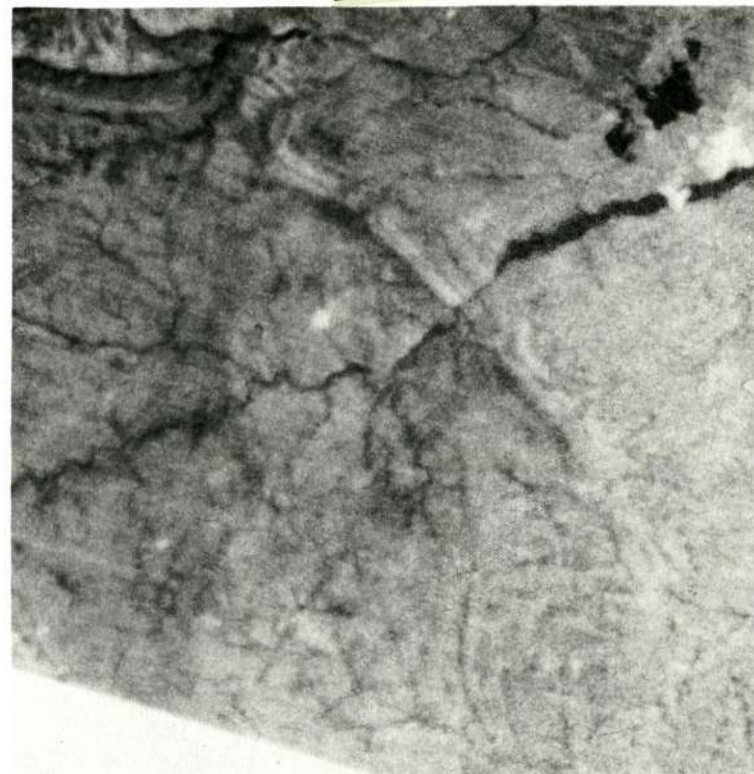
Figure 6—Reconnaissance geologic map of rocks of Precambrian age in the Granite Mountains and adjacent areas of Wyoming compiled by use of C-130 air photographs. Base map from Love (1970).



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A



B

Figure 7. Images of the southeastern Wind River Mountains of Wyoming showing contact between Precambrian metasedimentary rock - metavolcanic rock (dark mass on left) and granite-granite-gneiss; red band U-2 (A) and MSS-5 (B). The contact strikes approximately north and can be clearly seen in the left center of the images near the fork in the Sweetwater River. A contact between northeast dipping Paleozoic rocks and the Precambrian is in the northeast portion of each image.

Precambrian Terrain Distinctions Using C-130 Aircraft Photography

Five aircraft passes were made over portions of the Granite Mountains and the quality of the resulting color and color infrared photographs was excellent in all lines. These high resolution transparencies allow the interpreter to distinguish a great number of lithologic units. Within the meta-sedimentary rock - metavolcanic rock succession, hornblende gneiss and amphibolite could be distinguished and individual layers of amphibolite could be distinguished from hornblende gneiss in some hornblende gneiss areas using either color or color infrared film positives. More felsic metasedimentary units, (in part quartzite, mica [fuchsite] schist, and feldspathic quartzite) could be distinguished from the hornblende-rich units in some areas. In the central and western Granite Mountains units were mapped that appeared to be foliated igneous rocks of intermediate and mafic composition. Dikes of andesitic composition were distinguished from diabase dikes, and pegmatite dikes and sills were readily resolved. Granite and granite gneiss terrain is clearly distinguishable on the low altitude aircraft imagery and the initial field checks suggest that it is possible to distinguish strongly foliated or gneissic granite from more massive varieties.

These lithologic distinctions were made without use of available ground truth and prior to an August, 1972 field check. Figure 8 is a detailed map of the Barlow Gap area in the Granite Mountains made from interpretation of color and color infrared film positives from C-130 Mission 184. This area has not been mapped nor was the writer familiar with geology of the immediate area, but a brief one-day field check confirmed that the original photogeologic mapping was an essentially correct reconnaissance map of the area. Accurate distinction

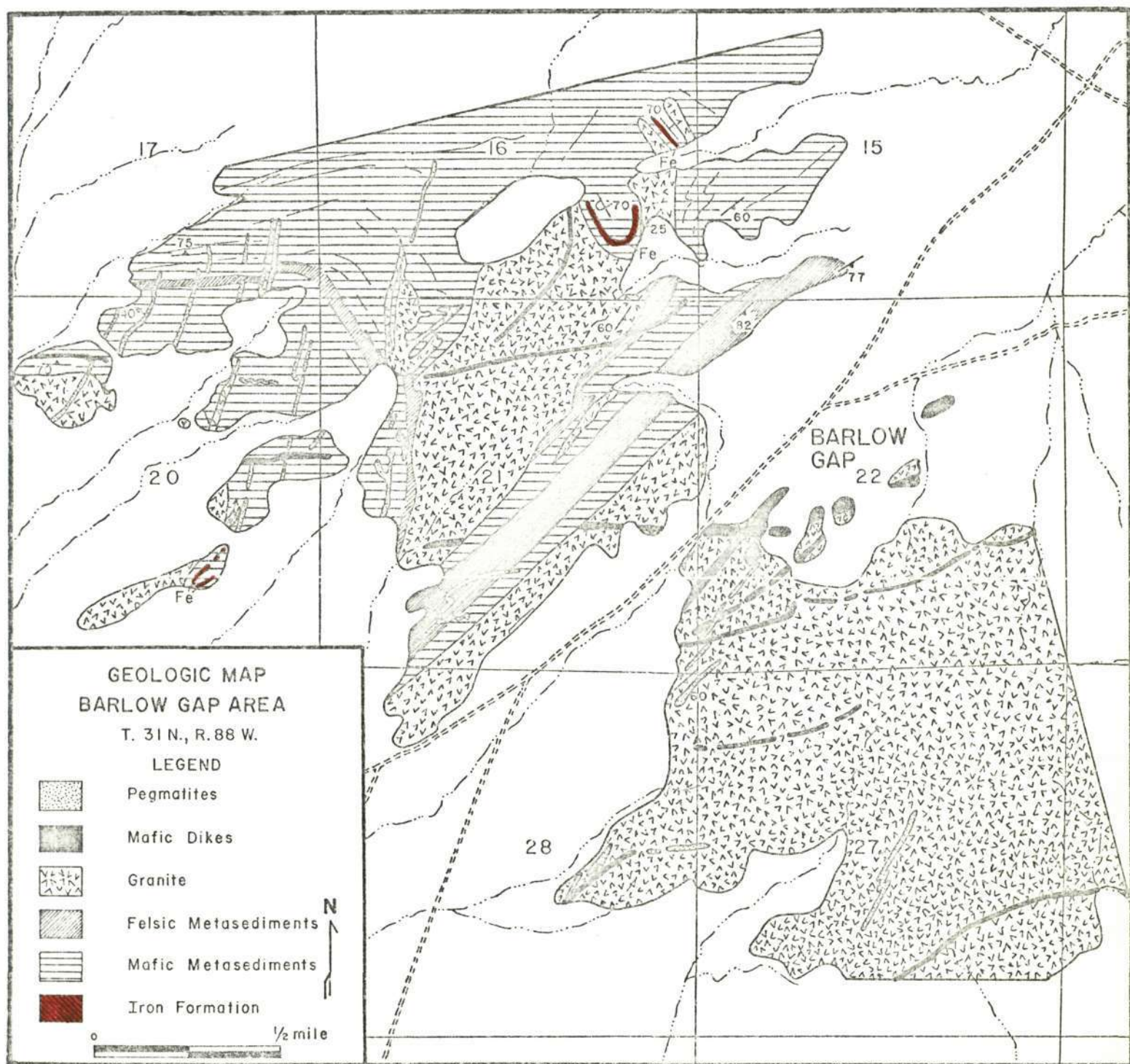


Figure 8. Geologic map of the Barlow Gap Area, Natrona County, Wyoming.

was made between granite-granite gneiss terrain and metasedimentary rock - metavolcanic terrain and, in addition, hornblende gneiss, amphibolite, felsic metasedimentary rocks, pegmatite, and mafic dikes were mapped. An important error in the original mapping was failure to distinguish between iron formation layers and amphibolite layers in the hornblende schist. The iron formation was identified in the field and was mapped as amphibolite in the photo-interpretation; it is shown on Figure 8 because of its economic importance and amphibolite layers that cannot be distinguished from iron formation are omitted since it was not possible to check each amphibolite layer in the field.

Figure 6 is a geologic map made from interpretation of the C-130 aircraft color and color infrared photography. If this map is compared with Figure 4, the reader may note that the photogeologic mapping compares favorably with the geologic maps, but several exceptions are apparent. In T. 30 N., Rs. 92 and 93 W. a series of outcrops of gneissic granite, biotite gneiss, and granite gneiss are exposed in secs. 16, 17, 18, 19, 20, 21, 30, and 31, T. 30 N., R. 92 W., and secs. 1, 2, 11, 12, 13, 14 and 24, T. 30 N., R. 93 W. (Fig. 6). According to Sherer (1969, p. 7-22) the biotite gneiss is a layered rock with alternating biotite-rich and quartz-feldspar-rich layers and it forms brownish-black to dark-gray outcrops whereas the gneissic granite and granite gneiss (both shown as granite in Figure 4) have less well developed layering are generally lighter in color than the biotite gneiss. These rocks are mineralogically similar, containing feldspar, quartz, and biotite chiefly with the primary difference being an increase in biotite and better developed layering in the biotite gneiss. They are not easily distinguished in the field because all units have gradational contacts and are inhomogeneous in mineral percentages. Thus, it is not surprising

that these units are not readily distinguished by photogeologic techniques. The biotite gneiss which is probably sedimentary in origin was interpreted as either granite or foliated granite by photogeologic techniques and contacts between the various units are not correct.

Iron Formation of the Barlow Gap Area

The area in the general vicinity of Barlow Gap is perhaps the best for photogeologic mapping in the Granite Mountains. The major rock types show strong color contrasts and lithologies show greater tonal and textural contrast on the film positives than in the field. As noted above iron formation was discovered in the area during a field check of the photogeologic map in August of 1972. This is the first report of iron formation in the Barlow Gap area, but a small body of iron formation was discovered in an area several miles northeast of Barlow Gap in 1971 by Alfred Pekarek (personal communication, 1971), graduate student at the University of Wyoming.

Three bodies of iron formation (Fig. 8) were noted at Barlow Gap in the one day reconnaissance survey of the area. The largest occurrence is in a small anticline (as indicated by primary structures in sedimentary rock noted in the field) located in SE 1/2, sec. 16, T. 31 N., R. 88 W. (Figs. 8 and 9). Oxide and silicate facies (James, 1954, p. 249) iron-formation were recognized. The oxide facies iron formation consists of layers of magnetite alternating with layers of green silicate and brown chert. The silicate facies is a laminated greenish black rock probably composed of minnesotaite and/or iron-rich amphiboles. Thin layers of iron-rich carbonate are also present, but the most abundant iron bearing rocks are the oxide facies type with alternating magnetite



Figure 9. Horseshoe-shaped bed of iron formation, Barlow Gap, Wyoming.

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and green silicate layers. Chemical analyses of these various rock types are in Table 1. The magnetite layered iron formation ranges from 21 to 29.5 percent iron which is about 5 percent less iron than the typical range for this facies as suggested by James (1954, p. 249).

ECONOMIC SIGNIFICANCE OF IRON FORMATION

The iron formation at Barlow Gap and that discovered by Alfred Pekarek northeast of Barlow Gap represents a series of small isolated outcrops (Fig. 10); none large enough to be of economic value at present and many factors in addition to tonnage (Ohle, 1972) must be considered before any firm conclusions about the economic value of the iron formation can be made. However, the geologic study of this area is only reconnaissance and the total areas of meta-sedimentary rocks where iron-formation outcrops are known covers at least 36 square miles. In addition to these outcrops Love (1970, C140) reports results of drilling which brought up numerous fragments of iron-formation from the Tertiary Wagon Bed Formation at a depth of 140-160 feet. These fragments of iron formation in the Tertiary beds were probably derived from iron formation in the Precambrian and the well in which they are found is in NW 1/2 sec. 14, T. 32 N., R. 86 W., 16 miles from the Barlow Gap area. These observations show that iron formation is present in Precambrian metasedimentary rocks in, at least, three townships and Figure 4 shows that similar metasedimentary rocks are present throughout much of the northern Granite Mountains. It is the writer's opinion (as was Love's (1970, p. C140) that this area should be studied to determine the extent of these iron bearing units.

Perhaps the most useful and least expensive tool for initial exploration would be an airborne magnetometer survey. Such a survey might locate iron formation both in surface outcrops and in Precambrian metasedimentary rocks that are buried beneath the relatively thin cover of Tertiary sedimentary rocks.

Table 1. Iron, manganese, titanium, and chromium content of samples of iron formation from Barlow Gap, Wyoming. (Analyst -- J. W. Murphy, Univ. Wyo. Rock Analysis Lab).

Rock Type	Sample No.	% Fe (\pm 0.2)	% Mn (\pm 0.003)	% Ti (\pm 0.1)	%Cr (\pm 0.02)
Silicate	RS72-2A	11.2	0.178	0.5	0.05
Silicate	RS72-2B	31.1	0.198	0.9	0.10
Carbonate	RS72-3A	6.1	0.162	0.9	0.19
Magnetite-Silicate layered	RS72-3B	21.0	0.213	0.9	0.06
Magnetite-Silicate layered	RS72-3C	29.5	0.268	0.9	0.10
Magnetite-Silicate layered	RS72-3D	21.0	0.164	0.9	0.06

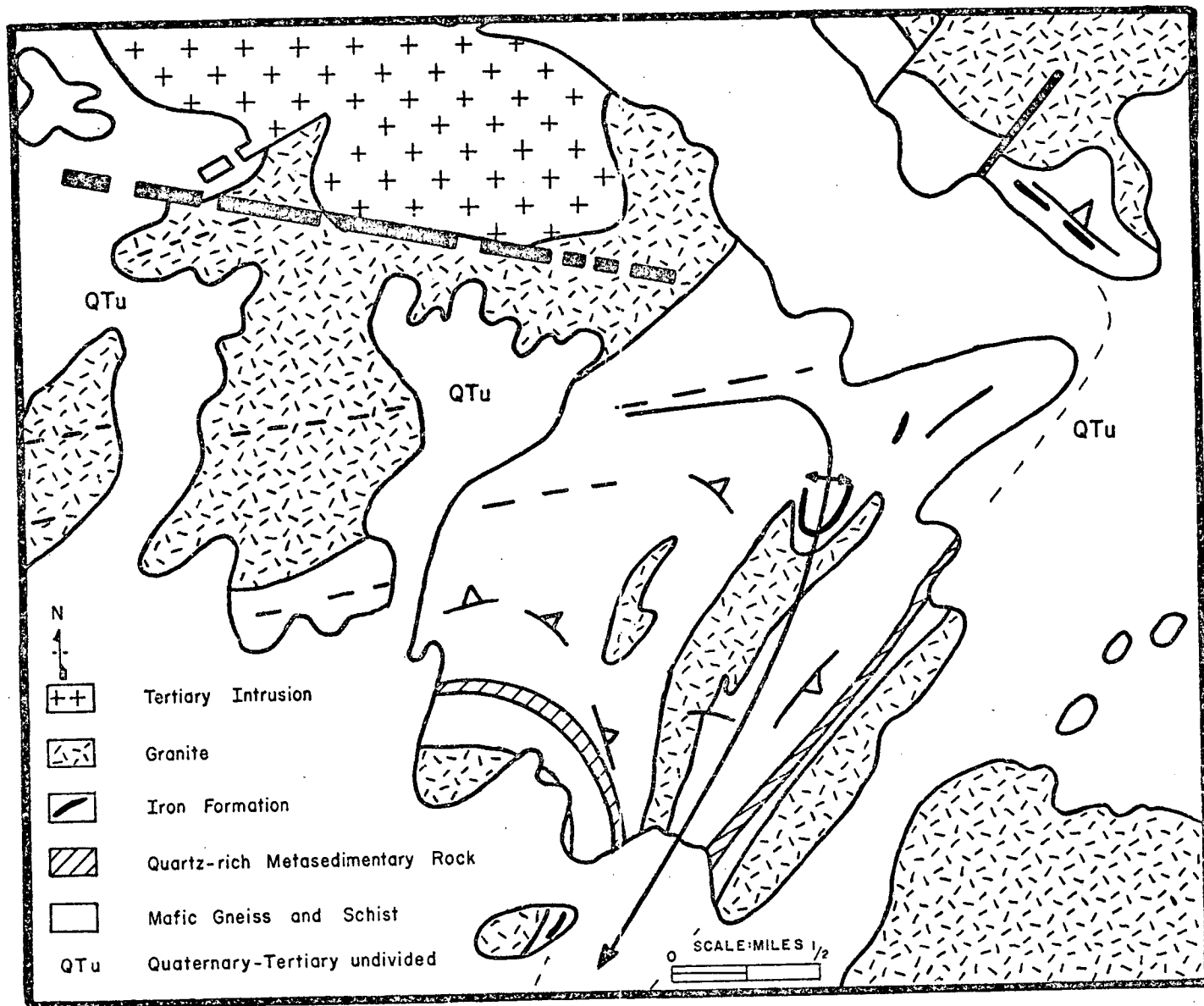


Figure 10- Sketch map showing possible folded fold at Barlow Gap and distribution of known Iron Formation.

Preliminary Structural Analysis of the Barlow Gap Area

Structural analyses from reconnaissance photogeologic mapping is, at best, preliminary. This is particularly true in rocks of Precambrian age where attitudes determined on layered units are not very reliable. These problems are compounded when mapped units have probably been subject to more than one period of deformation as is the case for much of the older Precambrian of the Wyoming Province (Houston, 1971, p. 20). Therefore, the reader must consider this structural analyses as a first approximation that will certainly be modified when this area is mapped in detail. The iron formation in SE 1/4, sec. 16, T. 31 N., R. 88 W., is an anticline, with its west limb overturned, and with an axis that plunges southeast. The bed of iron formation in the NE 1/4, SE 1/4, sec. 16, T. 31 N., R. 88 W. may be offset from the east limb of the anticline or may be a bed at a higher stratigraphic level. Inasmuch as these beds have primary sedimentation features which are diagnostic with respect to top and bottom this interpretation is reasonably accurate.

The major structure in these metasedimentary rocks is an antiform best shown in SE 1/4 sec. 17, NE 1/4 sec. 20, and E 1/2, sec. 21, T. 31 N., R. 88 W. This antiform plunges steeply northeast and as shown by trend lines in the sedimentary rocks, which are visible on the photography, and by limited field determinations of the attitude of foliation in beds of quartzite and mica (fuchsite) schist which appear to wrap around the nose of the northeast-plunging antiform and reappear in the E 1/2 sec. 21, T. 31 N., R. 88 W as a northeast striking layer dipping steeply southeast. This series of structures may be interpreted as folded folds with the axial plane of the first set folded about the second set as illustrated in Figure 10.

If this interpretation is correct the small body of iron formation noted in SE 1/4 sec. 20, T. 31 N., R. 88 W. should be higher in the stratigraphic succession than that in the small fold plunging southeast. If this unit is extrapolated around the axis of the compound fold it should reappear in layers dipping northeast in sec. 10, T. 31 N., R. 88 W. as noted in Figure 10 this is the approximate position of a bed of iron formation discovered earlier by Alfred Pekarek.

Evaluation of the Sensors for Distinction of Major Lithologic Types in
Rocks of Precambrian Age.

The red band (MSS-5, 0.6-0.7 μ m) of the Earth Resources Technology Satellite is the most useful in distinguishing metasedimentary - metavolcanic rock terrain (mafic) from granite-granite gneiss terrain (felsic). All other ERTS bands show the same spectral response for these rocks (i.e. generally darker tones for the metasedimentary-metavolcanic rocks) but the contrast between units is best in the red band. The second most useful ERTS band is infrared MSS-6 (0.7-0.8 μ m); and the band showing the least contrast in tone is the green band, MSS-4, (0.5-0.6 μ m). Inasmuch as spectral differences between bands appear small it is not surprising that multispectral viewing was not successful in differentiation of these particular rock units.¹ These results are essentially as predicted by Lyon (1970), who suggests that there may be no advantage to the geologist in the multispectral ERTS system since one band may be as valuable for lithologic distinction as several bands. This is apparently true for distinctions between these two types of rocks, but study of sedimentary successions (especially red beds) elsewhere in Wyoming suggests that in some instances the ERTS multiband approach is useful in rock discriminations.

¹We must emphasize that this failure to achieve enhancement by use of multispectral viewing was in the Granite Mountain area where image quality was poor and we have yet to study the better defined contacts of the Wind River Mountains because 70 mm transparencies are not available for this area. Therefore, we regard the statement on value of multispectral viewing as tentative.

The high-altitude aircraft data yields the same results as ERTS with the red band most useful in discrimination and the color infrared next.

The intermediate-altitude aircraft (C-130) results appear to be at variance with the above for several reasons:

1. The addition of color to the aircraft package gives perhaps the best sensor for the discrimination of rock types (Wilson, 1969, p. 22) at low altitude and this was essentially the case for these rock units.
2. The high resolution color infrared photography was nearly as useful as color in distinguishing these Precambrian rock types. Amphibolite and hornblende gneiss in particular give a characteristic spectral response in the near infrared portion of the spectrum and they contrast strongly with granitic terrain. This feature has been noted in similar rocks of the Beartooth Mountains of Montana and Wyoming by Rowan (1972). In general, both color and color infrared appeared equally useful in discrimination of these rocks at low altitude and generally the choice was made for mapping of the color or color infrared with the best exposure control.
3. In the intermediate-altitude aircraft package black and white infrared 2424/89B (700-1000 μm), red 2402/25A (590-700 μm), green 2402/57 (480-590 μm), blue and red 2402/32+2E (420-500 and 600-700 μm) and thermal infrared (8-14 μm) were studied. In contrast to results from ERTS and high-altitude aircraft, the black and white infrared was more useful than the red band in distinguishing these lithologies. The thermal infrared was also quite useful in that metasedimentary-metavolcanic rocks show a higher daytime thermal emission than granite.

Rowan (1972) notes that ectachrome-infrared photographs facilitate discrimination of amphibolite, basaltic dikes, and chrome-bearing ultramafic rocks (mafic lithologies) from granitic rocks (felsic lithologies) in the Bear-tooth Mountains of Montana and Wyoming. He relates this to the iron content of the rocks and points out that spectroscopic data demonstrate a major reflectance contrast between iron-rich (mafic) rocks and iron-poor (felsic) rocks in the near-infrared. Our results support Rowan in that we find the best tonal contrasts between felsic and mafic rocks in the infrared (both color and black and white) but this is for imagery obtained at low altitude. Visual examination of ERTS imagery suggests that the best tonal contrasts are in the red band rather than the infrared - the reverse of the low-altitude results.

Preliminary densitometric studies support results of the visual studies so that this is an area that obviously needs further research. We will continue to examine this problem, and report on the results after we have had an opportunity to obtain samples of rocks and vegetative cover in the areas in question.

CONCLUSIONS

Photogeologic techniques allow the geologist to subdivide rocks of Precambrian age into two broad categories - metasedimentary rock - metavolcanic rock terrain vs. granite-granite gneiss terrain, in parts of central Wyoming. The spectral signatures are not unique in that they do not allow a specific rock type to be identified but tonal contrasts plus other features of the rocks, such as structure, may be used by the experienced photogeologist, who must also have some first order experience with the lithologies, to make useful reconnaissance geologic maps. These major Precambrian rock units can be distinguished by use of MSS imagery from ERTS, high-altitude aircraft, and low-level aircraft with the expected increase in detail with higher resolution low-level aircraft imagery. ✓

Successful mapping with the MSS-ERTS sensor was dependent on atmospheric conditions and terrain. Atmospheric conditions were best on the ERTS pass of August 5th, 1972 and better lithologic distinctions could be made in the southeastern Wind River Mountains where greater areas are underlain by each of the two terrain types and where relief is relatively low within the area of Precambrian rocks. Lithologic distinctions could be made but with less accuracy in the Granite Mountains where relief is greater and the terrain is one of isolated bodies of Precambrian Rocks surrounded by sedimentary rocks of Tertiary age. Tonal contrasts between major lithologies were shown by all MSS-ERTS bands but the greatest contrast was displayed on MSS-5 or the red band. No advantage was gained from the use of a multispectral viewer in distinguishing the lithologies.

The U-2 aircraft images gave results similar to those of ERTS with better lithologic distinctions possible in the Granite Mountains than with ERTS. The most useful U-2 sensors were the red band and color infrared. The greater resolution of the U-2 images made it possible to map many of the large diabase dikes that cut granitic rocks in the Granite Mountains.

Low level C-130 aircraft images gave the best results because of the higher resolution and optimum sensors such as color and thermal infrared bands. Both color and black and white infrared images were especially useful in distinguishing these rock types at low altitude. Apparently, mafic lithologies such as hornblende gneiss and amphibolite have minimum spectral reflectances in the infrared or a characteristic vegetative cover that made them easy to distinguish with this band. The resolution of the low-altitude color and color infrared photography was such that fairly detailed reconnaissance geologic maps could be

made and it was possible to distinguish such units as amphibolite from hornblende gneiss. A brief field check of the photogeologic map of the Barlow Gap area in the Granite Mountains demonstrated that most of the lithologic distinctions were accurate, but some layers mapped as amphibolite proved to be iron formation of possible economic value.

The iron formation discovered through field checks of low-altitude aircraft imagery interpretations added to isolated bodies of iron formation reported in adjacent areas suggests that this part of the Wyoming Precambrian should be mapped in detail using geophysical and geologic techniques because economic deposits of iron formation may be present in outcrop or beneath the relatively thin cover of Tertiary sedimentary rocks.

This photogeologic study illustrates the value of multilevel sensing in mineral exploration. The ERTS sensors can be used to delineate areas of favorable terrain to be imaged in greater detail by aircraft and, despite the fact that individual mineral deposits of economic interest are not distinguished by aircraft images, the choice is narrowed further and field checks may be used to search for rock types of possible economic interest.

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